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Advanced Seismic Acquisition Survey Design Based on Illumination Analysis

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ABSTRACT

Full azimuth high-channel 3D seismic data acquisition has become an industry-standard for subsurface characterization. This is achieved on the receiver side through the continuous exponential increase in the number of recording channels over the years. On the source side, a tremendous effort is focused on improving the acquisition efficiency including the introduction of blended source acquisition, distributed recording systems and vibrator fleet management systems among other innovations. Thus, a small improvement in seismic survey design can lead to a substantial time and economic impact especially in mega acquisition projects. One of the key parameters of the seismic survey design is the nominal fold at the target level. Typically, a CMP fold is computed based on the source and receiver geometry and a simple 1D velocity earth model. This assumption, however, is true only if the target interface is flat and the earth model has no lateral velocity variations at the area of interest. Considering the size of modern 3D seismic surveys these two assumptions are often too weak. Another important factor is the near-surface variation that can be quite complex with rapid small-scale changes, especially in arid environments. As a result, the real target illumination can be significantly different from the nominal fold. This difference must be adressed at the survey design stage to ensure best possible target illumination with most efficient and cost effective acquisition, especially for imaging stratigraphic and low relief structures. In this paper, we propose adding target illumination analysis as an integral step in the survey design workflow. This illumination study can be achieved using wave-equation based methods but most of the time simple ray-tracing is more than capable for such analysis. The key ingredient for the ray-based illumination study is the velocity model. This model can be obtained from the previous sparse 3D studies or extrapolated from the nearest wells and seismic cubes using geostatistical methods. In case when a velocity model is available, two main products of the illumination analysis can be produced: illumination map at target horizon as well as rose diagrams at the points of interest. We demonstrate using a realistic synthetic earth model that even simple models with moderate levels of near-surface complexities can cause a visible difference between nominal fold and real target illumination.